

WHAT IS CLAIMED IS:

1. A scanning optical apparatus comprising:
light source means;
a deflecting element for deflecting a beam of
light emitted from said light source means;
optical means for causing the beam of light
emitted from said light source means to be imaged into
a linear shape long in the main scanning direction on
the deflecting surface of said deflecting element, said
optical means being comprised of a first optical
element and a second optical element; and
a third optical element for causing the beam of
light deflected by said deflecting element to be imaged
into a spot-like shape on a surface to be scanned, said
third optical element comprising a single lens, the
opposite lens surfaces of which both comprise a toric
surface of an aspherical surface shape in the main
scanning plane, the curvatures of said opposite lens
surfaces in the sub scanning plane being continuously
varied from the on-axis toward the off-axis in the
effective portion of the lens.
2. A scanning optical apparatus according to
Claim 1, wherein said light source means has a
plurality of light source units capable of being
independently modulated.

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3. A scanning optical apparatus according to
Claim 1, wherein when the curve amounts of the loci, in
the main scanning plane, of the front side principal
plane and the rear side principal plane of said third
5 optical element in the sub scanning direction (the
difference in the direction of the optical axis between
the most off-axis principal plane position and the on-
axis principal plane position) are x_m and x_u ,
respectively, the following condition is satisfied:

10 $x_m \leq dx \leq x_u$,

where

$$dx = \frac{I_{pri} \cdot E_{pri} (\cos \theta_{img} - \cos \theta_{por})}{I_{pri} \cdot \cos \theta_{por} + E_{pri} \cdot \cos \theta_{img}}$$

15 I_{pri} is the distance from the deflecting surface
of the deflecting element in the on-axis
beam to the front side principal plane in
the sub scanning direction;

20 E_{pri} is the distance from the rear side principal
plane in the sub scanning direction in the
on-axis beam to the surface to be scanned;

θ_{por} is the angle formed in the main scanning
plane by the most off-axis beam deflected
by the deflecting element with respect to
the optical axis;

25 θ_{img} is the angle formed in the main scanning
plane by the most off-axis beam incident
on the surface to be scanned with respect

to the optical axis.

4. A scanning optical apparatus according to
Claim 1, wherein the sign of the curvature of at least
5 one of the opposite lens surfaces of the single lens
constituting said third optical element in the sub
scanning plane is reversed from the on-axis toward the
off-axis.

10 5. A scanning optical apparatus according to
Claim 1, wherein said third optical element is made by
plastic molding.

15 6. A scanning optical apparatus according to
Claim 1, wherein said third optical element is made by
glass molding.

7. A scanning optical apparatus comprising:
light source means;
20 a deflecting element for deflecting a beam of
light emitted from said light source means;
optical means for causing the beam of light
emitted from said light source means to be imaged into
a linear shape long in the main scanning direction on
25 the deflecting surface of said deflecting element; and
an optical element for causing the beam of light
deflected by said deflecting element to be imaged into

a spot-like shape on a surface to be scanned, said optical element comprising a single lens, the opposite lens surfaces of which both comprise a toric surface of an aspherical surface shape in the main scanning plane, 5 the curvatures of said opposite lens surfaces in the sub scanning plane being continuously varied from the on-axis toward the off-axis in the effective portion of the lens.

10 8. A scanning optical apparatus according to
Claim 7, wherein said light source means has a
plurality of light source units capable of being
independently modulated.

15 9. A scanning optical apparatus according to
Claim 7, wherein when the curve amounts of the loci, in
the main scanning plane, of the front side principal
plane and the rear side principal plane of said optical
element in the sub scanning direction (the difference
20 in the direction of the optical axis between the most
off-axis principal plane position and the on-axis
principal plane position) are x_m and x_u , respectively,
the following condition is satisfied:

$x_m \leq dx \leq x_u$,

25 where

$$dx = \frac{I_{pri} \cdot E_{pri} (\cos \theta_{img} - \cos \theta_{por})}{I_{pri} \cdot \cos \theta_{por} + E_{pri} \cdot \cos \theta_{img}}$$

15 I_{pri} is the distance from the deflecting surface
of the deflecting element in the on-axis
beam to the front side principal plane in
the sub scanning direction;

10 E_{pri} is the distance from the rear side principal
plane in the sub scanning direction in the
on-axis beam to the surface to be scanned;

15 θ_{por} is the angle formed in the main scanning
plane by the most off-axis beam deflected
by the deflecting element with respect to
the optical axis;

20 θ_{img} is the angle formed in the main scanning
plane by the most off-axis beam incident
on the surface to be scanned with respect
to the optical axis.

25 10. A scanning optical apparatus according to
Claim 7, wherein the sign of the curvature of at least
one of the opposite lens surfaces of the single lens
constituting said optical element in the sub scanning
plane is reversed from the on-axis toward the off-axis.

25 11. A scanning optical apparatus according to
Claim 7, wherein said optical element is made by

plastic molding.

12. A scanning optical apparatus according to
Claim 7, wherein said third optical element is made by
5 glass molding.

13. A scanning optical apparatus comprising:
light source means having a plurality of light
source units capable of being independently modulated;
10 a deflecting element for deflecting a plurality of
independently modulated beams of light emitted from
said light source means;
optical means for causing the plurality of
independently modulated beams of light emitted from
15 said light source means to be imaged into a linear
shape long in the main scanning plane on the deflecting
surface of said deflecting element, said optical means
being comprised of a first optical element and a second
optical element; and
20 a third optical element for causing the plurality
of beams of light deflected by said deflecting element
to be imaged into a spot-like shape on a surface to be
scanned, said third optical element comprising a single
lens, the curvatures of the opposite lens surfaces of
25 said single lens in the sub scanning direction being
continuously varied from the on-axis toward the off-
axis in the effective portion of the lens.

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14. A scanning optical apparatus according to
Claim 13, wherein when the maximum value and minimum
value of the F number of the beam of light incident on
the surface to be scanned in the sub scanning direction
5 are Fmax and Fmin, respectively, the curvatures of the
opposite lens surfaces of the single lens constituting
said third optical element in the sub scanning
direction are continuously varied from the on-axis
toward the off-axis so as to satisfy the condition that

10 $F_{min}/F_{max} \geq 0.9.$

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15. A scanning optical apparatus according to
Claim 13, wherein the sign of the curvature of at least
one of the opposite lens surfaces of the single lens
15 constituting said third optical element in the sub
scanning direction is reversed from the on-axis toward
the off-axis.

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16. A scanning optical apparatus according to
Claim 13, wherein the curvatures of the opposite lens
surfaces of the single lens constituting said third
optical element in the sub scanning direction are
varied asymmetrically with respect to the optical axis
20 from the on-axis toward the off-axis.

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17. A scanning optical apparatus according to
Claim 13, wherein said third optical element is made by

plastic molding.

6. 18. A scanning optical apparatus according to
Claim 18, wherein said third optical element is made by
5 glass molding.

7. 19. A scanning optical apparatus comprising:
light source means having a plurality of light
source units capable of being independently modulated;
10 a deflecting element for deflecting a plurality of
independently modulated beams of light emitted from
said light source means;
optical means for causing the plurality of
independently modulated beams of light emitted from
15 said light source means to be imaged into a linear
shape long in the main scanning direction on the
deflecting surface of said deflecting element; and
an optical element for causing the plurality of
beams of light deflected by said deflecting element to
20 be imaged into a spot-like shape on a surface to be
scanned, said optical element comprising a single lens,
the curvatures of the opposite lens surfaces of said
single lens in the sub scanning direction being
continuously varied from the on-axis toward the off-
25 axis in the effective portion of the lens.

8. 20. A scanning optical apparatus according to

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Claim 19, wherein when the maximum value and minimum value of the F number of the beam of light incident on said surface to be scanned in the sub scanning direction are F_{max} and F_{min} , respectively, the 5 curvatures of the opposite lens surfaces of the single lens constituting said optical element in the sub scanning direction are continuously varied from the on-axis toward the off-axis so as to satisfy the condition that

10 $F_{min}/F_{max} \geq 0.9.$

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21. A scanning optical apparatus according to
Claim 19, wherein the sign of the curvature of at least one of the opposite lens surfaces of the single lens 15 constituting said optical element in the sub scanning direction is reversed from the on-axis toward the off-axis.

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22. A scanning optical apparatus according to
Claim 19, wherein the curvatures of the opposite lens surfaces of the single lens constituting said optical element in the sub scanning direction are varied asymmetrically with respect to the optical axis from the on-axis toward the off-axis.

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23. A scanning optical apparatus according to
Claim 19, wherein said optical element is made by

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plastic molding.

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24. A scanning optical apparatus according to
Claim 19, wherein said optical element is made by glass
5 molding.

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25. A scanning optical apparatus comprising:
light source means having a plurality of light
source units capable of being independently modulated;
10 a deflecting element for deflecting a plurality of
independently modulated beams of light emitted from
said light source means;
optical means for causing the plurality of
independently modulated beams of light emitted from
15 said light source means to be imaged into a linear
shape long in the main scanning direction on the
deflecting surface of said deflecting element, said
optical means being comprised of a first optical
element and a second optical element; and
20 a third optical element for causing the plurality
of beams of light deflected by said deflecting element
to be imaged into a spot-like shape on a surface to be
scanned, said third optical element being comprised of
at least two lenses, the curvatures of at least two
25 lens surfaces of said two lenses in the sub scanning
direction being continuously varied from the on-axis
toward the off-axis in the effective portion of the

lens.

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26. A scanning optical apparatus according to
Claim 25, wherein when the maximum value and minimum
5 value of the F number of the beam of light incident on
said surface to be scanned in the sub scanning
direction are F_{max} and F_{min}, respectively, the
curvatures of at least two lens surfaces of the two
lenses constituting said third optical element in the
10 sub scanning direction are continuously varied from the
on-axis toward the off-axis so as to satisfy the
condition that

$$F_{min}/F_{max} \geq 0.9.$$

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27. A scanning optical apparatus according to
Claim 25, wherein the sign of the curvature of at least
one lens surface of said two lenses constituting said
third optical element in the sub scanning direction is
reversed from the on-axis toward the off-axis.

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28. A scanning optical apparatus according to
Claim 25, wherein the curvatures of at least two lens
surfaces of the two lenses constituting said third
optical element in the sub scanning direction are
25 varied asymmetrically with respect to the optical axis
from the on-axis toward the off-axis.

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33 A scanning optical apparatus according to
Claim 25, wherein at least one of the two lenses
constituting said third optical element is made by
plastic molding.

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33 A scanning optical apparatus according to
Claim 25, wherein at least one of the two lenses
constituting said third optical element is made by
glass molding.

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31. A scanning optical apparatus comprising:
light source means having a plurality of light
source units capable of being independently modulated;
a deflecting element for deflecting a plurality of
15 independently modulated beams of light emitted from
said light source means;
optical means for causing the plurality of
independently modulated beams of light emitted from
said light source means to be imaged into a linear
shape long in the main scanning direction on the
20 deflecting surface of said deflecting element; and
an optical element for causing the plurality of
beams of light deflected by said deflecting element to
be imaged into a spot-like shape on a surface to be
25 scanned, said optical element being comprised of at
least two lenses, the curvatures of at least two lens
surfaces of said two lenses in the sub scanning

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direction being continuously varied from the on-axis toward the off-axis in the effective portion of the lens.

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31. 19. A scanning optical apparatus according to Claim *31*, wherein when the maximum value and minimum value of the F number of the beam of light incident on said surface to be examined in the sub scanning direction are F_{max} and F_{min} , respectively, the curvatures of at least two lens surfaces of the two lenses constituting said optical element in the sub scanning direction are continuously varied from the on-axis toward the off-axis so as to satisfy the condition that

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$$F_{min}/F_{max} \geq 0.9.$$

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31. 19. A scanning optical apparatus according to Claim *31*, wherein the sign of the curvature of at least one lens surface of the two lenses constituting said optical element in the sub scanning direction is reversed from the on-axis toward the off-axis.

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31. 19. A scanning optical apparatus according to Claim *31*, wherein the curvatures of at least two lens surfaces of the two lenses constituting said optical element in the sub scanning direction are varied asymmetrically with respect to the optical axis from

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the on-axis toward the off-axis.

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35. A scanning optical apparatus according to
Claim *31*, wherein at least one of the two lenses
5 constituting said optical element is made by plastic
molding.

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36. A scanning optical apparatus according to
Claim *31*, wherein at least one of the two lenses
10 constituting said optical element is made by glass
molding.

